



Storm Tides of the Fundy

Con Desplanque; David J. Mossman

Geographical Review, Vol. 89, No. 1. (Jan., 1999), pp. 23-33.

Stable URL:

<http://links.jstor.org/sici?sici=0016-7428%28199901%2989%3A1%3C23%3ASTOTF%3E2.0.CO%3B2-5>

Geographical Review is currently published by American Geographical Society.

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at <http://www.jstor.org/about/terms.html>. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at <http://www.jstor.org/journals/ags.html>.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

The JSTOR Archive is a trusted digital repository providing for long-term preservation and access to leading academic journals and scholarly literature from around the world. The Archive is supported by libraries, scholarly societies, publishers, and foundations. It is an initiative of JSTOR, a not-for-profit organization with a mission to help the scholarly community take advantage of advances in technology. For more information regarding JSTOR, please contact support@jstor.org.

STORM TIDES OF THE FUNDY

CON DESPLANQUE and DAVID J. MOSSMAN

ABSTRACT. Historically, storm tides wreaked havoc in the Bay of Fundy. With the tidal system resonating at close to the 12-hour, 25-minute dominant lunar tide of the Atlantic Ocean, variations in normal Fundy tides are in the main caused by astronomical factors. The strongest Fundy tides occur when the three elements—anomalous, synodical, and tropical monthly cycles—peak simultaneously. The closest match occurs at intervals of 18.03 years, a time known as the *Saros*. Problems arise when storms coincide with these intervals. A strong *Saros* has coincided with several major historical storm tides in the Bay of Fundy, including the 1976 Groundhog Day storm, the 1869 Saxby Tide, and the 1759 storm tide. With continuing global sea-level rise and regional crustal subsidence, the possible recurrence of destructive storm tides has grave implications for property owners and settlements in the Fundy coastal zone. *Keywords:* Bay of Fundy, coastal hazards, *Saros*, storm tides.

According to Pytheas, tides north of Britain rise to heights of 36.6 meters.

—Pliny the Elder [A.D. 23–79], *Historia Naturalis*, 1962

Storm tides, whether positive or negative, generally spell trouble. A positive storm tide, or storm surge, is a large rise in water level accompanying a coastal storm caused by violent winds and low atmospheric pressure. Conversely, under conditions of high atmospheric pressure, a negative storm tide may lower sea level well below its predicted value (Parkes, Ketch, and O'Reilly 1997). When a storm tide coincides with an exceptionally high astronomical tide and shallow water depths, the results may be little short of catastrophic. The record of storm tides is knowable, and they may be predictable in the Gulf of Maine–Bay of Fundy region. We begin with a look at some of the events associated with the most historically memorable Fundy storm tide, the Saxby Tide of 4–5 October 1869.

THE SAXBY TIDE, 1869

On the afternoon of 4 October, Thomas Earle tried to leave Beacon Light, at Sand Point in Saint John Harbour, New Brunswick, but the heavy seas drove him back (Figure 1). As wind and waves continued to rise, water flooded the first floor of his lighthouse and threatened to go even higher. Waves broke over the top of the tower, more than 10 meters tall, carrying away the bell and smashing the windows and the globe protecting the gaslight. Retreating to the middle story, the keeper closed the hatchway behind him. But the gaslight continued to burn and, fanned by the storm, ignited the superstructure. Earle managed to extinguish the fire and fit a spare globe around the light. Three and a half hours later the tide receded sufficiently to allow him to gain the safety of higher ground.

* MR. DESPLANQUE is a retired hydraulic engineer living in Amherst, Nova Scotia, Canada B4H 2A8. DR. MOSSMAN is a professor of geoscience at Mount Allison University, Sackville, New Brunswick, Canada E4L 1E6.



FIG. 1.—Beacon Light at Sand Point, Saint John Harbour, New Brunswick, replaced the first Beacon Light, which was destroyed by fire in 1867, two years before the Saxby Tide. Beacon Light, declared surplus, was destroyed in 1913. Sand Point is now the terminus of the Canadian Pacific Railway. (Photograph from a postcard)

At home in a region of world-record high tides, Earle, like most coastal folk, would have known the difference between spring tides and neap tides.¹ He knew that storms can cause unusually high tides—storm tides or storm surges—especially when they coincide with an otherwise normal astronomical high tide. Usually he would have relied on the *Farmers' Almanac* to predict tidal conditions throughout the year. But conditions in the Bay of Fundy on 4–5 October 1869 were hardly usual.

Earle may never have heard of Pliny the Elder—or of Sir Thomas Herschel, who, in 1860, helped sustain the legend of 36.6-meter-high tides by repeating the myth of the fourth-century B.C. Greek navigator, Pytheas. However, Earle probably had read in local newspapers about S. M. Saxby's dire prediction of the great storm from which he only narrowly escaped. The prediction had first appeared in the British newspapers the *London Standard* and the *London Press* almost a year earlier, in November 1868. It read:

I now beg to state with regard to 1869 at 7:00 A.M., October 5, the Moon will be at the part of her orbit which is nearest the Earth. Her attraction, will be therefore at its maximum force. At noon of the same day the Moon will be on the Earth's equator, a circumstance which never occurs without marked atmospheric disturbance, and at 2 P.M. of the same day lines drawn from the Earth's centre would cut the Sun and Moon in the same arc of right ascension (the Moon's attraction and the Sun's attraction will therefore be acting in the same direction); in other words, the new Moon

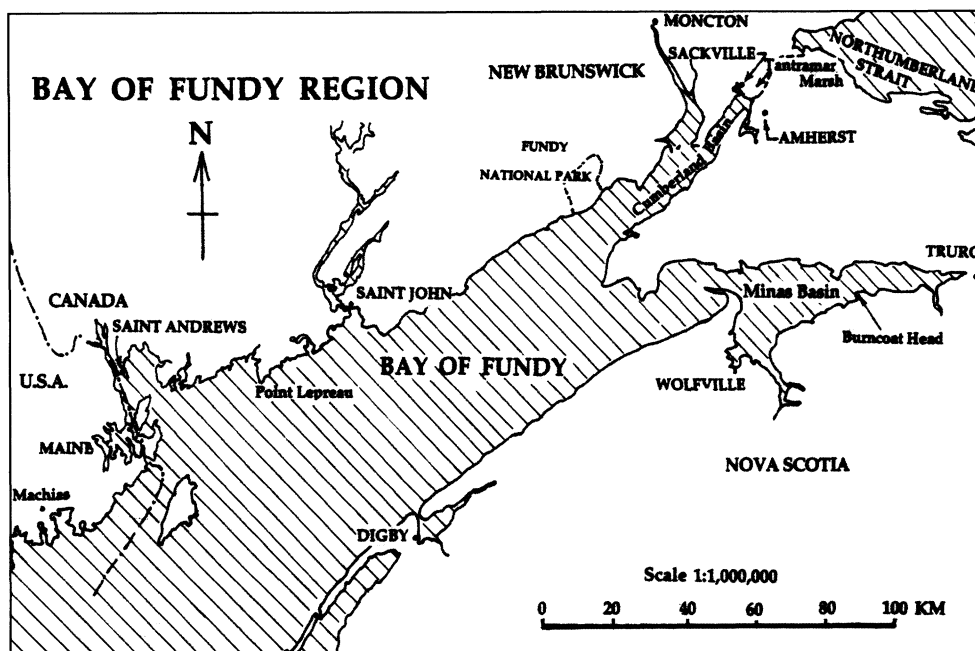


FIG. 2—The Bay of Fundy region.

will be on the Earth's equator when in perigee, and nothing more threatening can, I say, occur without miracle. With your permission, I will, during September next (1869) for the safety of mariners, briefly remind your readers of this warning. In the meantime, there will be time for repair of unsafe sea walls, and for the circulation of this notice throughout the world.

Saxby, a civilian instructor of naval engineers of the British Royal Navy, published books and almanacs of weather predictions, claiming a relationship between stormy weather and the moon crossing through the plane of the earth's equator. However, because this occurs every two weeks, it could be said that Saxby gave himself a better than 50 percent chance of claiming reliable forecasts. Note that Saxby did not specify where his threatening tide would occur. Astronomic conditions were to be right for higher-than-normal tides, worldwide, on 5 October 1869.

The prediction was fulfilled in the Bay of Fundy by what was to become known as the "Saxby Tide" or "Saxby Gale" (Figure 2). A storm hit the North American eastern seaboard on 4 October 1869, causing severe flooding and wind damage. Between Washington, D.C., and the upper reaches of the Bay of Fundy, more than 150 vessels sank or were blown ashore, 121 of them between Saint Andrews, New Brunswick, and Machias, Maine. Near Point Lepreau, New Brunswick, the bark *Genii* was wrecked, and eleven lives were lost.

At 5:00 p.m. the wind increased to a gale, and an hour later it began to rain. By evening Saint John's streets were littered with debris torn from buildings. The gale

continued from the south, reaching hurricane force at about 9:00 P.M., by which time the rain had stopped. At around 10:00 P.M. the wind shifted to the southwest and subsided. Fully an hour and a half before the tide ordinarily would have reached its peak, waves from the Bay of Fundy were breaking over every wharf in Saint John Harbour. Ships parted from their moorings: Some were driven ashore; others were badly damaged. Dozens of wharves, fish shacks, and abutments were washed away (Ganong 1911; Tibbets 1967; Maclean 1979).

Some 160 kilometers to the northeast, at the head of the Bay of Fundy, the Saxby Tide occurred at 1:00 A.M. on 5 October, overtopping the dykes by at least 0.9 meters. In the Cumberland Basin two fishing schooners were lifted over the dykes of the Tantramar marshes and deposited 5 kilometers inland. At Moncton, New Brunswick, the water rose nearly 2 meters above the next highest tide on record. On the marshes west of Amherst, Nova Scotia, a barn in which some people had been sleeping was dispatched well over 1 kilometer up the marsh. During the course of the storm, two men were carried out to sea and drowned; three others were able to cling to timbers and eventually were washed ashore. Much of the hay stored on the marsh was swept out to sea, and the remainder was scattered all over the area. Farmers drew lots in order to divide what little hay was salvaged. In and around the Minas Basin the gale was less severe, although the rainfall was heavy. Everywhere, dykes were breached, cattle and sheep were drowned, and lengthy portions of railroad beds were washed away; and in many areas travel became impossible. Communications likewise were shut down by the weather to a degree difficult for us to imagine today.

A year after the disaster a survey was conducted, between 13 August and 31 December, for a proposed canal across the Chignecto Isthmus from the Bay of Fundy to the Northumberland Strait. To simplify calculations, by avoiding negative values, the surveyors assumed a datum (reference elevation) of 100 feet below the average top elevation of the dykes. By this reckoning, the Saxby Tide was reported to have reached levels of 30.48 meters or more. These figures, of course, have no direct relationship to mean sea level. But they have, unfortunately, helped perpetuate the erroneous notion of enormous tides.

During the 1870 survey extremely high astronomical tides—those not associated with storms—occurred on 23 September (28.83 meters), 26 October (28.83 meters), and 23 November (28.80 meters), for an average of 28.82 meters. Comparing this elevation with the average top elevation of the dykes yields a difference of 1.79 meters (30.48 meters minus 28.82 meters). Thus, although the level of the dykes may have been raised slightly in the years since 1870, the Saxby Tide was at least 1.5 meters higher than astronomically caused high tides.

THE STORM TIDE OF 1759

Only sparse accounts survive of a probable precedent, more than 100 years earlier, for the Saxby Tide: the nameless historical storm tide that battered the Bay of Fundy region on 3–4 November 1759. In Beamish Murdock's "History of Nova Scotia," contained in the *Gentleman's Magazine* of 1760, it is recorded that at Fort Cumberland

(earlier and later named Fort Beausejour) 700 cords of firewood were swept away from a wood yard that was at least 3 meters above the protecting dyke. In Saint John Harbour water reportedly rose 1.8 meters higher than was usual for large tides. Storm waves broke on the terraces of Fort Frederick, located well inside the harbor, demolishing a storehouse and spilling provisions into the sea.

It is unknown whether anyone foretold the historical storm tide of November 1759. The regionality of storms and storm tides makes predictions like Saxby's an unscientific exercise, however much they may impress the local populace. Even today meteorologists, assisted by a worldwide computerized network of data-gathering instruments on the ground, at sea, and in satellites, are faced with more variables than they are able to handle (Wells 1986). The precise behavior and frequency of complex extraordinary weather systems, their whereabouts, strength, rate, and direction of movement, are beyond meteorologists' grasp.

THE GROUNDHOG DAY STORM, 1976

Although the Saxby Gale was predicted a year before it happened, the "Groundhog Day" storm of 2 February 1976 was forecast only at the last moment. Two days earlier, a weak low-pressure area hovered over Alabama and Texas. Subsequently, this system met a small high-pressure system from western Ontario. Small-craft warnings were issued on 1 February, advising of strong southerly winds. Then, around noon that day, gale-force winds were predicted. During the night, gale warnings were upgraded to severe storm warnings. By 8:00 A.M. on 2 February the barometric pressure had dropped precipitously over the Gulf of Maine, signaling an alert to the likelihood of a storm accompanied by higher-than-normal tides.

The storm hit the coast of Maine hard (Morrill, Chin, and Richardson 1979). In places the tide rose more than 2.5 meters above the predicted level, heavily eroding the coastline. Waves hammered coastal installations. A freighter anchored in Penobscot Bay was blown aground. The strong south-southeasterly winds, which had been blowing for five to six hours over the open water along the major axis of the Penobscot Bay, resulted in a storm surge in the bay and up the Penobscot River. Much of the city of Bangor was flooded. In less than 15 minutes the water reached its maximum depth of 3.7 meters in the river, 3.2 meters above the predicted tide level.

By the afternoon of Groundhog Day the storm was raging all along the eastern seaboard (Figure 3). Intermittent power failures and curious sparking effects were the result of short circuits caused as winds swept seawater across the countryside. Fortunately, the tide was an apogean spring tide (Conkling 1995). In Saint John, the high tide was expected to be only 7.7 meters above Chart Datum at 1:10 P.M. Note that, for comparative purposes, this is almost exactly equal to mean Higher High Water (7.71 meters) at Saint John. However, on the afternoon of Groundhog Day the tide rose to 9.16 meters above Chart Datum, fully 1.46 meters higher than expected. The damage would have been enormous had the storm occurred on the perigeon spring tides: Sixteen days later, on 18 February, the tide at Saint John was predicted to reach a height of 8.4 meters above Chart Datum; a month and a half later, on



FIG. 3—Two Irving Oil Company ships broke their moorings and crashed into a causeway 1.6 kilometers from downtown Saint John, New Brunswick, as gale-force winds slammed into the area on Groundhog Day, 2 February 1976. (Photograph reproduced courtesy of the *Saint John Telegraph Journal*)

18 March, 8.66 meters above Chart Datum; and two and a half months later, on 16 April, 8.84 meters above Chart Datum, 1.07 meters higher than the predicted tide on Groundhog Day. In short, a storm on 16 April 1976 would have had the potential of causing calamity on the scale of the Saxby Tide.

SAXBY, THE SAROS, AND TIDES

Saxby might have added to his prediction that the great storm tide destined to immortalize him in the view of many Maritimers would coincide with the *Saros* (Desplanque 1974). *Saros* is a Babylonian word used to describe an astronomical cycle of 18 years, 11 days, and 8 hours. In this 18.03-year cycle, the moon, the sun, and the earth return to almost identical relative positions. It is astounding to realize that, by 800 B.C., Chaldean priests knew the *Saros* well enough to accurately predict eclipses. Eclipses occur when the sun, the moon, and the earth are in, or near, a straight line. Could it be that eclipses—or, more particularly, the time intervals between eclipses—are associated with far-higher-than-normal tides? Evidence is strong that this is the case. A review of the cause of tides and their variations speaks to the implications of the *Saros* and the likelihood of a future tide comparable to the Saxby Tide.

As first elucidated by Sir Isaac Newton (1642–1727), tides are caused by the gravitational attraction of the sun and moon on water particles near the surface of the

earth. In general, the average gravitational effect of the sun is about 46 percent that of the moon; however, in the Bay of Fundy the effect of the sun is only about 15 percent that of the moon. Furthermore, because the orbits of the earth around the sun and the moon around the earth are elliptical and because their paths are influenced by many factors, the gravitational effects are variable in strength, like tides (House 1995).²

Normal tides are termed astronomical tides because their main variations are generated by three astronomical phenomena:

- Variable distance between the moon and the earth. This causes the greatest deviations from the average (mean) tide in the Bay of Fundy. Because the moon's orbit is an ellipse, once a month, when the moon is closest to the earth and thus the gravitational pull is the greatest, the tides are stronger than average. These are called "perigean" tides, and the cycle in which they recur is the "anomalistic month" of 27.555 days.
- Variable positions of the moon, the sun and the earth relative to each other. The cycle of the moon's phases in which there are two sets each of "spring" and "neap" tides is the "synodical month" of 29.531 days.
- Declination of the moon and the sun relative to the earth's equator. Declination is the angular distance between a heavenly body and the celestial equator (the plane in which the earth's equator is situated). A complete cycle, during which the moon crosses the equator twice, lasts 27.322 days and is called a "tropical month."

Additional astronomical factors that influence tides include the earth's rotation and the eccentricity of the moon's orbit, which varies depending on the sun's position in relation to the longest axis of the moon's orbit. Local nonastronomical phenomena include the possible increase in the tidal range in the Bay of Fundy due to deepening waters (Godin 1992); atmospheric disturbances; the geometric shape of inlets, bays, and ocean basins; and the postglacial rise in sea level. This last factor translates to about a 2-millimeter-per-year submergence of the land worldwide in relation to sea level (Schneider 1997).

The Bay of Fundy is a special case, of course (Greenberg 1987). Bordered at its outer limit by the edge of the continental shelf, the bay's tidal system has a resonance period of about 13 hours, close to the 12-hour, 25-minute dominant lunar tide of the Atlantic Ocean. The Atlantic tidal pulse pushes waters of the Gulf of Maine and the Bay of Fundy at nearly the optimum interval to achieve maximum ebb and flow under normal conditions. Indeed, the maximum range between low and high tides in the world was recorded at 16.29 meters on 16 July 1916 by Dr. W. Bell Dawson, superintendent of tidal surveys, at Burncoat Head in the Bay of Fundy.

The most favorable combination of factors to produce strong tides in the Bay of Fundy occurs when perigee coincides with spring tide at the very time that anomalistic, synodical, and tropical months peak simultaneously. As it happens, the best match occurs after a period of 6,585.3 days (18.03 years) (Table I). The driving

TABLE I—ANALYSIS OF ASTRONOMICAL CYCLES GOVERNING TIDES^a

PERIGEAN	SPRING	DECLINATIONAL	PERIOD
7P = 192.88	13S = 191.95	14D = 191.25 solar days	0.53 years
60P = 1,653.27	112S = 1,653.71	121D = 1,652.96 solar days	4.53 years
239P = 6,585.54	446S = 6,585.32	482D = 6,584.50 solar days	18.03 years

^a Analysis using simple multiples of astronomical cycles governing tides shows that the peaks of P = perigean cycles (27,554 days), S = spring tides (14,765 days), and declinational cycles (13,661 days) closely coincide at the intervals given. The closest coincidence occurs at an interval of 18.03 years (circa 6,585 days).

TABLE II—MULTIPLES OF THE SAROS^a

SAROS	YEARS	DAYS
Cycle 1	18	11
Cycle 2	36	23
Cycle 3	54	34
Cycle 4	72	45
Cycle 5	90	57
Cycle 6	108	68
Cycle 7	126	79
Cycle 8	144	91
Cycle 9	172	102
Cycle 10	180	113
Cycle 11	198	125

^a Multiples of the 18.03-year Saros cycle, corrected for leap years. This cycle, first recognized by the ancient Chaldeans, corresponds with the interval at which solar and lunar eclipses are repeated.

mechanism of this cyclical phenomenon is the same one that orders the timing of eclipses; namely, the Saros.

Given the clockwork precision of astronomical conditions and their dictate over normal tide variations, it is reasonable to enquire whether the Saxby Tide—and, for that matter, other historical storm tides in the Bay of Fundy—coincided with the Saros. What are the chances of a periodic storm system of the magnitude associated with the name “Saxby”? The only certainty is that the relationships between the moon and the sun that produce the highest tides on earth are repeated in the same periods as are those that create solar and lunar eclipses (Abell, Morrison, and Wolff 1988): the Saros cycle of 18.03

years. Therefore, to check the position of a historical high tide in the Saros, one need only add to the tide’s date the appropriate multiple of the Saros to reach a particular time interval for which the tidal record is well known. Detailed tidal records in Canada were first kept in about 1894. So, as a reference point, a date can be chosen at the end of 1958, which is eleven Saros after the Saxby Tide. The tidal levels referred to are those measured at Saint John, where the average high tide is 7.7 meters above Chart Datum. To test the reliability of this method of prediction, examples of historical storm tides can now be checked against predicted tides, *n* Saros cycles later (Table II).

In checking the multiples of the Saros against storm tides, the storm tides of 1759 and 1869 correlate very closely with predicted high tides of the Saros cycle (Table III). So do the exceptionally high water of 12 October 1887, experienced in Moncton, and the storm tides of 20–22 December 1995. The latter occurred exactly seven Saros cycles after the Saxby Tide; indeed, their occasion was hinted at by Desplanque (1974; see also Taylor and others 1996). However, it is important to bear in mind, through any exercise of this type, that Saros cycles are long-term, harmonic motions. This means that, near the top or bottom of the cycle, the rate of change with

TABLE III—COUNTBACK OF TIDES IN THE BAY OF FUNDY AT 18.03-YEAR INTERVALS, SHOWING THAT THE HISTORICAL STORM TIDE OF 3-4 NOVEMBER 1759 AND THE SAXBY TIDE OF 4-5 OCTOBER 1869 CLOSELY COINCIDE WITH PREDICTED HIGH TIDES OF THE SAROS

Comparison of the 1759 storm tide with the high tide at Saint John eleven Saros cycles later, on 8 March 1958:

	DATE	DAY IN THE YEAR
Historical high tide (1759)	3 November	307
<u>add 198 days</u>		<u>125</u>
1957		432 days = 1958 + 67 days (8 March 1958)

The predicted high tide for 8 March 1958 was 8.75 meters.

Comparison of the Saxby Tide, 1869, with the high tide at Saint John five Saros cycles later, on 1 December 1959:

	DATE	DAY IN THE YEAR
Saxby Tide (1869)	5 October	278
<u>add 90 days</u>		<u>57</u>
1959		335th day in 1959 (1 December 1959)

The predicted high tide for 1 December 1959 was 8.84 meters.

time is relatively small. The “peaks” of Saros cycles are not points in time but rather short intervals of time.

DÉJÀ VU?

Should property owners along the Bay of Fundy be reminded of their next appointment with the Saros in A.D. 2012–2013? The question is not trivial: With increasing encroachment of people in coastal zones, the risk of loss of life and major property damage in the Gulf of Maine–Bay of Fundy region is substantial in the event of a tide like the Saxby Tide (Shaw and others 1994). Simply put, what is the probability of a storm tide coinciding with a large astronomical tide?

A “peak” of the Saros occurred between 6 March 1958 and 31 December 1959. During this time, there were 1,288 tides at Saint John, 37 of which were extreme astronomical high tides (8.69 meters or higher). The probability that an historically memorable storm tide coincided with one of the 37 tides is slightly less than 3 percent. This assumes that the occurrence of stormy weather conditions is spread evenly throughout the year. The increased incidence of high winds during late spring and fall probably bumps the odds of gale-force conditions coincident with high tides up to slightly more than 3 percent.

Is postglacial sea-level rise a significant factor in all of this? Most assuredly the answer is yes, because with each repeat of the Saros, an increase of the high-tide mark of at least 3.6 centimeters (2 millimeters per year for 18 years) can be expected. Since the Saxby Tide, more than seven Saros ago, the sea level has risen nearly 25 centimeters as a result of the melting of glaciers in response to global warming. This figure, added to the minimum 1.5 meters by which the Saxby Tide exceeded high as-

tronomical tides, gives a height more than sufficient to overrun the present dyke system.

CONCLUSIONS

Could tides like the Saxby Tide be recurrent? It seems likely, although one wishes for a larger database. Astronomical conditions exert absolute control over normal tidal variations. But much remains to be learned about long-term periodic events associated with tides and the weather. We have seen that only significant storms coincident with large tides, or extraordinarily severe storms coincident with medium tides, can result in higher tide marks than are reached by astronomical tides alone. Detailed tidal records over several decades show that in the Bay of Fundy there is a tendency for slightly higher maximum monthly high-water marks in a 4.5-year-cycle, with the next peak predicted for 2002. Indeed, in this region high perigean tide levels can be anticipated at intervals of 1 month, 7 months, 4.5 years, and 18 years. When such high-tide levels coincide with severe atmospheric disturbances, exceptionally high water surfaces can be expected. However, short of an extraterrestrial catastrophe, they are not likely to attain the 36.6-meter height of legend.

NOTES

1. During the moon's elliptical orbit about the earth, its various phases define the spring and neap tidal conditions. Spring tides result when the earth, the moon, and the sun are aligned during full and new moons. Neap tides occur during the moon's first and last quarters. The largest spring tides occur when the moon is at its perigee.
2. The earth's equator makes an angle of about 23.5° (actually, 23.452°) to the plane (ecliptic) in which it moves around the sun. The noonday sun at the summer solstice stands over 23.5° N; at the winter solstice, over 23.5° S. Adding to the earth's tilt, the moon is at an angle of about 5° to the ecliptic. The monthly swing was 57.2° during November 1987 but decreased to 36.6° in February 1997, only to increase again to 57.2° over the following 9.3-year period. Thus, the amount of (maximum) declination of the moon's orbit is constantly varying.

REFERENCES

- Abell, G. O., D. Morrison, and S. C. Wolff. 1988. *Realm of the Universe*. 4th ed. Philadelphia: Saunders College Publishing.
- Conkling, P. W., ed. 1995. *From Cape Cod to the Bay of Fundy: An Environmental Atlas of the Gulf of Maine*. Cambridge, Mass., and London: MIT Press.
- Desplanque, C. 1974. The Saros and the Saxby Tide. Unpublished document C.D.74.1.21. Amherst, Nova Scotia: Maritime Resource Management Service.
- Ganong, W. F. 1911. A Preliminary Study of the Saxby Gale. *Bulletin of the Natural Historical Society of New Brunswick* 29 (6), part 3: 325–339.
- Godin, G. 1992. Possibility of Rapid Changes in the Tide of the Bay of Fundy, Based on a Scrutiny of the Records from Saint John. *Continental Shelf Research* 12 (2–3): 327–338.
- Greenberg, D. A. 1987. Modeling Tidal Power. *Scientific American* 257 (1): 128–131.
- House, M. R. 1995. Orbital Forcing Time Scales: An Introduction. In *Orbital Forcing Time Scales and Cyclostratigraphy*, edited by M. R. House and A. S. Gale, 1–18. Geological Society Special Publication No. 85. London: Geological Society.
- Maclean, P. 1979. The Saxby Gale. *Atlantic Advocate*, January, 44–47.
- Morrill, R. A., E. H. Chin, and W. S. Richardson. 1979. *Maine Coastal Storm and Flood of February 2, 1976*. U.S. Geological Survey Professional Paper 1087. Washington, D.C.: Government Printing Office.
- Parkes, G. S., L. A. Ketch, and C. T. O. O'Reilly. 1997. Storm Surge Events in the Maritimes. Paper presented at the Canadian Coastal Conference, Halifax, Nova Scotia, March 1997.

- Pliny the Elder. 1962. *Historia Naturalis* (Natural History). Vol. 10, translated and edited by D. E. Eichholz. London: W. Heinemann.
- Saxby, S. M. 1868. Letter to the *London Standard*. November.
- Schneider, D. 1997. The Rising Seas. *Scientific American* 276 (3): 112–117.
- Shaw, J., R. B. Taylor, D. L. Forbes, M.-H. Ruz, and S. Solomon. 1994. *Sensitivity of the Canadian Coast to Sea-Level Rise*. Open File Report 2825. Ottawa: Geological Survey of Canada.
- Taylor, R. B., D. Forbes, D. Frobel, J. Shaw, and G. Parkes. 1996. Shoreline Response to Major Storm Events in Nova Scotia. In *Climate Change and Climate Variability in Atlantic Canada, Workshop Proceedings*, edited by R. W. Shaw, 253–268. Occasional Report No. 9. Halifax, Nova Scotia: Environment Canada, Atlantic Region.
- Tibbets, D. C. 1967. The Saxby Gale. *Atlantic Advocate*, October, 62–64.
- Wells, N. 1986. *The Atmosphere and Ocean: A Physical Introduction*. London and Philadelphia: Taylor and Francis.